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13. ABSTRACT *(Maximum 200 words)*
Combat support roles for female soldiers expose them to extremes of both environment and physical exertion. Our goals were to quantify female performance under extreme conditions and to evaluate using male-based models to predict female performance. We collected data on 4 female soldiers performing tasks related to litter casualty evacuation in a hot-dry environment. Activities consisted of walking (1.34 m×s-1) and self-paced two person litter carriage (68 kg load) to simulate casualty evacuation. Uniforms were worn with (MOPP-4) and without (MOPP-0) Chemical Protective (CP) clothing and masks. There were statistically significant differences ($p=0.006$) between MOPP-0 and MOPP-4 for rectal temperature (DTre) while walking, but not for litter carriage. The primary limiting factor for litter carriage was muscular-skeletal strain. Without CP clothing, thermal strain was not the immediate limiting factor. Data for Tre were compared to values calculated with the Heat Strain Decision Aid (HSDA) and SCENARIO models. The Root Mean Squared Deviations (RMSD) from the observed Tre values were compared to the mean standard deviations (`S`D). Both male-based models were applicable to the female subject population. The HSDA demonstrated better fit, but SCENARIO is more suitable for accurate and direct input of intermittent work.

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WOMEN LITTER CARRIERS: OBSERVATION AND MODELING

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INTRODUCTION

Combat support roles for female soldiers expose them to extremes of both environment and physical exertion. We investigated tasks related to the evacuation of casualties by litter. Our goals were to quantify female performance under extreme conditions and to compare the efficacy of using male-based models to predict female performance.

MATERIALS AND METHODS

Data were collected on 4 female soldiers in a hot-dry environment (1). Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research. Subjects participated in these studies after giving their free and informed voluntary consent. Test activities consisted of walking (1.34 $m \cdot s^{-1}$) forward to the casualty and self-paced 2-person litter carriage (68 kg load) to simulate stages in casualty evacuation. Metabolic costs for rest, walking and litter carriage were measured prior to testing. Litter carriage was intermittent work consisting of a series of short carries separated by rest periods. Clothing consisted of the Battledress Uniform (BDU) or the Battledress Overgarment (BDO). The BDU provided no chemical protection (MOPP-0 condition), whereas the BDO was worn with the M-40 mask (MOPP-4 condition). Data for rectal temperature (T_{re}) were compared to values calculated with the Heat Strain Decision Aid (HSDA) (2) and SCENARIO (3) models. The HSDA model is an executable version of the USARIEM Heat Strain Model (4) developed to predict soldier performance. Model inputs are air temperature, relative humidity, wind speed, solar radiation, clothing, activity or metabolic rate and values for soldier height and weight and heat acclimation. The SCENARIO model was developed as a post hoc model to evaluate experimental results and requires additional inputs of maximum oxygen uptake and globe or mean radiant temperature. Although SCENARIO allows direct input of time-indexed metabolic rates, the HSDA does not. Consequently, metabolic inputs for the HSDA consisted of weighted average values that included a time adjustment to compensate for the metabolic cost of each lift.

RESULTS

Table 1 presents mean meteorological data used as modeling inputs, and Table 2 summarizes the test results. Mean values for subject height and weight were respectively 162 ± 1 cm and 63 ± 5 kg. There were statistically significant differences between MOPP-0 and MOPP-4 for ΔT_{re} ($P = 0.006$) while walking, but not for litter carriage. The primary limiting factor for litter carriage was muscular-skeletal stress.

Table 1. Environmental conditions during walking (W) and litter carriage (L) test activities in MOPP-0 (BDU) or MOPP-4 (BDO) clothing

	Meteorological values (SD)						
Test	T_a °C	T_g °C	wind $m \cdot s^{-1}$	RH %	WBGT °C	T_{rad} °C	T_{grnd} °C
W-BDU	39.41 (0.43)	51.11 (0.96)	2.49 (0.98)	12.57 (1.00)	28.9 (0.5)	82.20 (6.87)	52.95 (1.30)
W-BDO	37.96 (0.27)	47.05 (0.44)	4.82 (1.25)	17.85 (0.52)	28.3 (0.3)	84.05 (4.72)	50.52 (0.21)
L-BDU	37.82 (0.34)	46.42 (0.65)	4.63 (1.13)	17.72 (1.57)	28.1 (0.4)	81.12 (4.86)	49.80 (1.17)
L-BDO	35.46 (0.33)	42.21 (1.98)	4.82 (1.10)	26.79 (1.10)	27.4 (0.8)	71.53 (7.30)	46.38 (1.60)

Table 2. Summary of subject responses by activity[1]

Test	T_{re}, °C	ΔT_{re}, °C	Endurance time in minutes *range*	*mean*
W-BDU	38.33 (0.42)	0.93 (0.27)	80-160[2]	140 (40)
W-BDO	38.55 (0.26)	1.28 (0.40)	20-37	29 (8)
L-BDU	37.86 (0.50)	0.69 (0.51)	28-107	59 (35)
L-BDO	38.00[3] (0.50)	0.76[3] (0.41)	22-57[3]	43[3] (19)

[1] Values in parentheses are Standard Deviations
[2] Maximum time for any activity was 160 min
[3] Three subjects, otherwise n=4

Figures 1 and 2 plot the outputs from both models with mean T_{re} values. The Root Mean Squared Deviations (RMSD) (5) from the observed T_{re} values were compared to the mean standard deviations (SD). For all days and models (4x2), with one exception, RMSD ≤ SD. Overall, the HSDA model fit the data better. For litter carriage, the 2-day average RMSD for HSDA was 0.06 vs. 0.10 for SCENARIO.

DISCUSSION

With the exception of walking with chemical protection (MOPP-4), T_{re} values remained below 38.5°C. This indicates that factors other than thermal strain were limiting performance. Figures 1 and 2 show that both models project the general response patterns, although T_{re} is clearly overpredicted for walking in MOPP-4. When HSDA was used to model male performance during another study (6), the rate of increase in core temperature was overpredicted. It may be

desirable for a predictive model to provide a conservative estimate of core temperature, and thus provide some margin for error. The comparison of modeling results to this limited data set suggests there may be no such margin for error when the model is run with inputs for a female population.

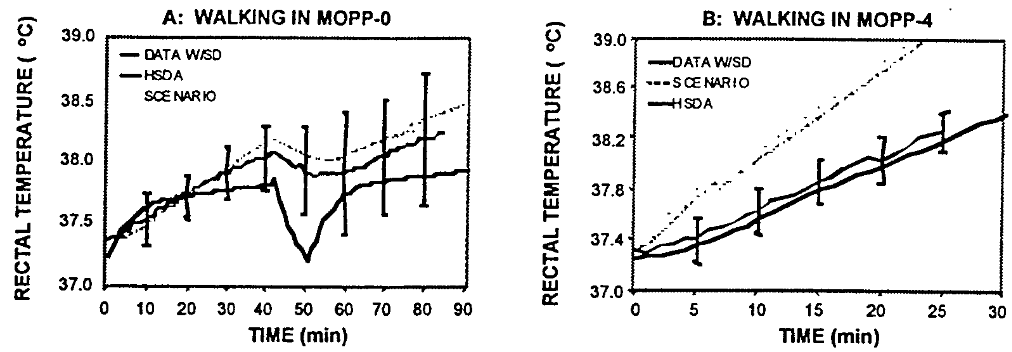

Figure 1. Comparison of observed mean T_{re} to modeling results for walking in MOPP-0 (A) and MOPP-4 (B)

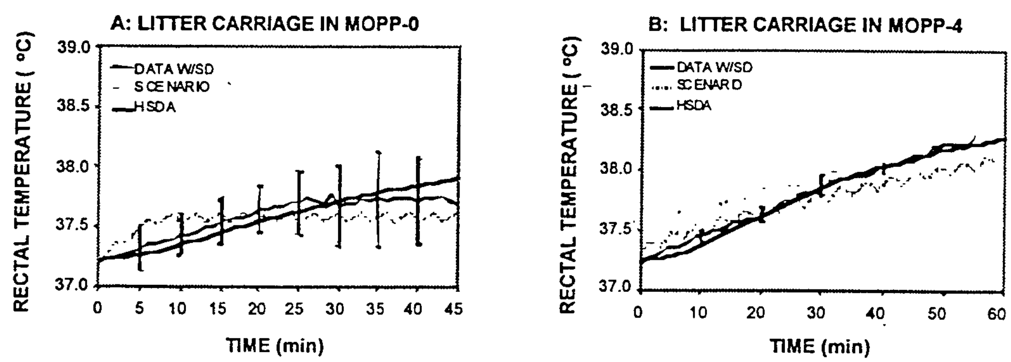

Figure 2. Comparison of observed mean T_{re} to modeling results for litter carriage in MOPP-0 (A) and MOPP-4 (B)

CONCLUSIONS

The results indicate that strength and equipment are limiting factors for litter carriage regardless of chemical protection (CP) clothing or weather condition. Without CP clothing, thermal strain was not the immediate limiting factor. For modeling, an accurate estimate of metabolic cost of each activity is critical. Both male-based models were applicable to our female subject population. The HSDA demonstrated better fit, but the format of SCENARIO is more suitable for direct input of metabolic rates for intermittent work.

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